Analysis of Willingness To Pay in Guaranteed Multiple-Priority Service

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ABSTRACT

Differentiated services, which have multiple classes using priority control, have recently been introduced. Various issues need to be addressed when providing multiple-priority, such as what sort of quality should be guaranteed, and what kind of pricing should be applied to the service. In this paper, the quantitative relation between the guaranteed bandwidth and Willingness to pay (WTP) is shown by the questionnaire survey. We also did a factor analysis using regression and Quantification Method I to identify the factors that affect WTP. We identified that the main factors that affect the potential WTP are the number of usage days per week and over-midnight usage. And we also showed that the main factors that affect the sensitivity of the increase in WTP are the bandwidth at response time and the usage duration per day.

1. INTRODUCTION

The Internet has so far only been able to support uniform "best-effort" services, where available bandwidth is sometimes severely limited due to network congestion, but recently there has been a growing need for services with guaranteed quality. In particular, recent research has been focused on differentiated services which use priority control techniques to provide users with a guaranteed bandwidth.

In a differentiated service, a higher charge can be imposed on the user with quality of service requirements to allow a high degree of satisfaction. Because users select services to satisfy their own needs, they will naturally withdraw from services with high charges and subscribe to services with low charges. In this way, efficient use of network resources and optimum user satisfaction can be achieved at the same time by making use of the user's selection with respect to charges.

The relation between user satisfaction with a service and the charge for the service has been well researched [1-3]. There have also been many studies on quality and utility in fields such as quality evaluation [4,5]. Nevertheless, user utility and WTP with respect to guaranteed bandwidth remains virtually unstudied. Therefore, we here focus on the relationship between guaranteed bandwidth and WTP and investigate the factors that affect WTP.

In this paper, we first define multiple-priority service and then clarify the relation between the quality and WTP with a questionnaire survey. The service referred to in the questionnaire is the core network guaranteed bandwidth service, and for simplicity the charging system is assumed to be given a fixed value. We obtained mean opinion scores from the questionnaire results and used them to approximate empirical measurement function by the least-squares method. We also did a factor analysis using regression and Quantification Method I to identify the factors that affect WTP.

2. MULTIPLE-PRIORITY SERVICE

With the appearance of new services such as content distribution, the demand for quality guarantees in IP networks is increasing. Therefore, network enterprises such as Internet service providers are looking into services that offer multiple classes of quality by employing priority control. Here, we define such a service as a differentiated service.

With multiple-priority, it is expected that multiple class best-effort services or guaranteed bandwidth service will be offered. The former can be provided using DiffServ [6] priority control while the latter can be provided with IntServ [7] priority control. Of the two types of priority control, DiffServ is easier to implement, but WTP is difficult to investigate because best-effort service does not provide constant quality. We therefore chose the guaranteed bandwidth service using IntServ for the initial phase of investigation, and collected questionnaire data on the relation between guaranteed bandwidth and WTP.

We assume the following service model for the differentiated service.

・Access line
Flat-rate basic service
・The core network (bandwidth guaranteed service)
Flat-rate optional services

The term access line refers to a line that connects the user terminal to the access point. The bandwidth of the access line is guaranteed. The core network begins at the access point and is the backbone line that interconnects provider's network and the networks of different providers.

Currently, the core network only provides services in which the bandwidth is divided up among many persons, and no person has a guaranteed bandwidth. Here, we report the results of a questionnaire concerning user WTP for guaranteed core network bandwidth service, assuming a new service in which the bandwidth of the core network is guaranteed.

3. Questionnaire survey

The questionnaire was designed to test the following hypothesis.

Hypothesis: *There is a positive correlation between guaranteed bandwidth and WTP.*

To test the assumption, it is necessary to quantify the relation between guaranteed core network bandwidth and WTP. WTP is the value a customer is willing to pay for a service. Because it can indicate the limit of utility to the user, it is used as a measure of utility [8,9].

The overall design of the questionnaire is shown in Table 1. The questionnaire is intended to investigate WTP with respect to bandwidth guaranteed by priority control.

The response format of the questionnaire was for the respondents to answer freely by simply filling in their WTP. The evaluation figures for the services are presented as optional charges added to a basic rate. Ten guaranteed core network bandwidths were presented in the questions: 100 kbps, 200 kbps, 500 kbps, 1 Mbps, 2 Mbps, 5 Mbps, 10 Mbps, 20 Mbps, 50 Mbps and 100 Mbps. The questions also inquired the user on his/her age, sex, occupation, Internet connection environment, line speed at the time of response, as well as the Internet usage frequency and the time of day.

Table 1. Design of questionnaire

Number of sample data	100
Target people	Internet users
Research method	Free answer type (Respondents write the price for each bandwidth service in the answer form.)

4. Results of questionnaire

There were 59 effective respondents to the questionnaire (49 males and 10 females). The attributes of the respondents are listed in Table 2. Their mean age is 26.6 years. By occupation, there are 28 company employees and 31 students. The mean speed of the line normally used is 5.6 Mbps, and the mean speed at the time of response is 1.5 Mbps. However, the standard deviation and kurtosis are large in the probability distributions for both values. Accordingly, variance is detected in the available access line speed, but most of the data is concentrated within a few particular ranges.

The mean frequency of use is six days per week. The distribution has a negative skew of -1.73, which indicates a bias to the right side of the distribution mean. This we can interpret as an indication that most people use the Internet nearly every day. The mean connection time is also a long period of 3.85 hours per day. This questionnaire revealed that both the frequency of use and the connection time are high, and that many of the respondents use the Internet often.

Table 2. Results of questionnaire

	Average	Standard deviation	Kurtosis	Skewness
Line speed at the time of response	1595kbps	2274	2.74	7.50
Internet connection environment	5609kbps	7578	2.85	10.6
Age	26.6	6.00	2.07	5.35
Frequency of use per week	6 day	1.66	-1.73	2.07
Connection time par day	3.85 houres	3.45	1.89	3.41

5. Estimating the WTP function

On the basis of the questionnaire results, we obtained the WTP for the overall service with respect to bandwidth. The WTP for a particular service is the sum of the WTP for the access line basic service and the WTP for the core network optional service. The WTP values were summed for each guaranteed bandwidth, and their mean values were taken to be the mean opinion scores (MOS). The MOS $\bar{u}$ was calculated by

$$\bar{u}_v = \frac{1}{n}\sum_{i=1}^{n} W_{iv} , \quad (1)$$

where i is the number of respondent, n is number of respondents, v is optional bandwidth.

The MOS obtained this way is used to estimate the user WTP function by employing the least squares method. For the approximation, linear, logarithmic, exponent and power approximations were used.

We determined the applicability of the four functions from their contribution rates. The WTP function contribution rates are listed in Table 3 in order of increasing contribution. Contribution rates closer to 1 indicate a higher degree of applicability. We can see that the power approximation has the highest contribution, and so it is the best choice for approximating the WTP function. The WTP function so approximated is shown in (2), where guaranteed bandwidth is represented as v and WTP as U.

Table 3. Contribution rates

Approximation	Contribution rates
Linear approximation	0.762
Logarithmic approximation	0.969
Exponent approximation	0.631
Power approximation	0.997

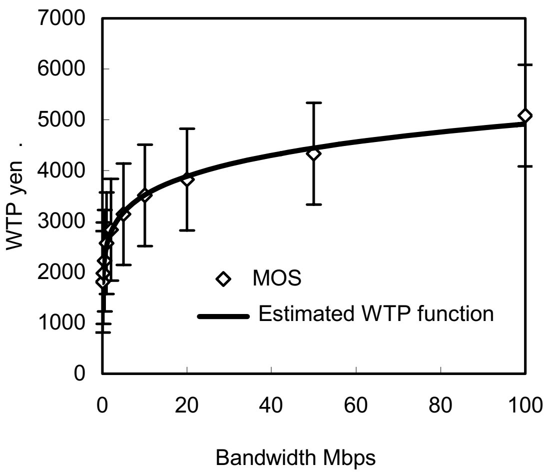

Figure 1. Relation between bandwidth and WTP.

$$U = 2.51 \times 10^{3} v^{1.46 \times 10^{-1}} . \quad (2)$$

The WTP function obtained by power approximation and the MOS values are shown in Fig.1. The vertical axis of the graph represents WTP and the horizontal axis is the guaranteed bandwidth. As the guaranteed bandwidth increases, the WTP also increases.

6. FACTOR ANALYSIS

We used the questionnaire results for user attributes to perform factor analysis for WTP. For the quantitative data variables, we used regression analysis while, Quantification Method I was used for the qualitative data variables. The Quantification Method I is a method of estimating the value measured quantitatively based on the information about a qualitative factor.

First, we estimated WTP functions for individual user WTP. Here, power approximation based on the results described in the previous section was used to estimate the WTP function. The estimated WTP function is expressed by (3), where WTP is represented by W and the guaranteed bandwidth is represented by X.

$$W = PX^{s} . \quad (3)$$

Here, P represents a parameter for the user's potential WTP. A large value for this parameter means that users are generally willing to pay high rates. The s is a parameter that represents the sensitivity of the increase in the user WTP. If the value of s is large, the increase in user WTP is high in proportion to the increase in guaranteed bandwidth.

Regression analysis and Quantification Method I are used for prediction and extraction of main factors by making use of the relationship between one variable and another variable. The variable to be predicted is referred to as the objective variable while the variable that serves as the basis of prediction is called the explanatory variable. When applied to factor analysis, the objective variable must be the variable that represents the results and the explanatory variable must be the variable that represents the cause.

For the explanatory variable, we chose the user attributes of age, sex, occupation, Internet connection environment, bandwidth, line speed at time of response and frequency of Internet use, and over-midnight use. Generally, it is said that the Internet's busiest time comes between 11:00 pm and 2:00 am. We therefore specified a variable for whether or not the Internet is used during that time frame.

To investigate the validity of the regression, we employed the contribution rate with adjusted degrees of freedom. The level of significance of the explanatory variable as determined with a t test was 0.05.

We first did the factor analysis with potential WTP, denoted as P, as the objective variable. The regression analysis yielded the regression equation shown in (4), for which the explanatory variable is significant while the contribution rate with adjusted degree of freedom is maximum. Explanatory variable X is the number of days per week of Internet usage.

$$P = -1.74 \times 10^{-1} X + 2.78 \times 10^{3} . \quad (4)$$

Using Quantification Method I, the regression equation is given in (5). The contribution rate with adjusted degree of freedom is nearly 1. In this case, the explanatory variable X belongs to over-midnight category.

$$P = -7.67 \times 10^{2} X + 2.74 \times 10^{3} . \quad (5)$$

Next, we analyzed the factors of the sensitivity of the increase in WTP, *s*. The regression analysis yielded the regression equation shown in (6). The contribution rate with adjusted degree of freedom is nearly 1. The explanatory variables are as follows. X_1 is the line speed at the response time, X_2 represents the age, X_3 the number of usage days per week, and X_4 stands for time connected per day.

$$s = 1.14\times10^{-5} X_1 + 1.64\times10^{-3} X_2 - 1.56\times10^{-3} X_3 + 9.08\times10^{-3} X_4 + 6.89\times10^{-2} \quad (6)$$

A regression equation that contains multiple explanatory variables may include superfluous variables. Such a regression equation has a decreased power of prediction. Applying *t* tests using the variable summation and subtraction method for selection of the explanatory variables revealed that the age and number of usage days per week variables have low significance. Excluding those variables results in (7), where X_1 is the line speed at the time of responding and X_2 is the amount of usage time per day.

$$s = 1.00\times10^{-5} X_1 + 8.47\times10^{-3} X_2 + 1.08\times10^{-1}. \quad (7)$$

Furthermore, analysis by Quantification Method I showed that none of the explanatory variables were significant.

The analysis described above shows that the potential WTP is directly affected by the number of usage days per week and over-midnight usage. The results also show that the sensitivity of the increase in WTP is directly affected by the line speed at the time of response and the usage time per day.

7. Summary and Conclusion

We have described a guaranteed bandwidth service as a kind of differentiated service in which guaranteed bandwidth of the core network is assumed to support differentiated services. We then presented the results of a questionnaire survey concerning user WTP with respect to the core network guaranteed bandwidth service.

The questionnaire was intended to determine user's WTP fixed monthly charges for a basic service and an optional service. Mean opinion scores were calculated from the overall results of the questionnaire and used to estimate a WTP function by applying the least squares method. We found that the power function approximation was effective.

Factor analysis by regression and Quantification Method I revealed that the main factors that affect the potential WTP are the number of usage days per week and over-midnight usage. Analysis also showed that the main factors that affect the sensitivity of the increase in WTP are the line speed at the response time and the amount of usage duration per day.

In the future work we will investigate methods of bandwidth distribution control for each class as well as methods for setting the charges per class with the objective of maximizing overall user's utility and network provider's revenue. Provision of guaranteed bandwidth as differentiated service will be considered. Disaggregate behavioral model will be used to indicate user's behavior, i.e. whether or not the user joins the guaranteed bandwidth service. Disaggregate behavioral model has a number of advantages, such as high validity and possibility of statistical verification. By applying this model, it is possible to calculate user's utility and attractiveness of the service to the user, which would result in maximizing overall user's utility and network provider's revenue.

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